



A Systematic Review and Meta-Analysis on the Most Useful Key Performance Indicators in Measuring and Evaluating Healthcare Performance

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ABSTRACT

The healthcare performance measurement system is a critical indicator for assessing hospital management performance. This study aims to identify the most frequent critical performance indicators (CSFs) in measuring and evaluating healthcare performance. This paper conducts a systematic review based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). A literature review that includes "key performance indicators for health facility management (FM) or analyzing the most used key performance indicators," and an in-depth view were used to classify relevant KPIs for healthcare FM performance measurement. The findings show that patient satisfaction, cash flow, infection rate, length of stay, average waiting time, number of accidents per year, incidents and errors, and bed occupancy are the most significant CSFs for health facility management (HFM). The results of this paper provide valuable insights to inform future KPI development for the Yemeni healthcare environment. In future work, the Delphi method and the analytic hierarchy process (AHP) will be employed to prioritize the performance indicators of the Yemeni healthcare environment.

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1. INTRODUCTION

During the last decade, the structures of healthcare systems have changed [1, 2]. One of the most important economic sectors in the world today is the healthcare system, which is also essential to a healthy social and communal life [3]. According to the extent of development and complexity of hospital data, which may be obtained in a variety of forms, including employees' information, patient records, clinical results, diagnosis, prescription, medical imaging techniques, mobile healthcare, and any available resources, the rapid advancement of technology, life-changing environment, and unstable environment lead to trouble in healthcare decision-making [4, 5].

A performance evaluation system is the procedure of assessing the achievement of an organization in attaining its goals and objectives [6]. The primary objective of performance measurement is to assist an organization in comprehending its present performance and enhancing its ongoing efforts for future growth and decision-making [7, 8].

KPIs are deliberated as performance-based decision-making tools for hospital managers and stockholders at nationwide and home-grown levels [9]. These pointers as indicators give managers accurate findings on time, which enables them to assess their strengths and weaknesses and also enhances managerial performance [10]. Within the healthcare sector, developing KPIs

for assessing and measuring healthcare performance has a significant effect on enhancing the quality of services [11]. Thus, it helps managers, hospital administrators, and clinicians monitor performance and payment systems by evaluating clinical and economic performance indicators [12]. Using one-dimensional performance indicators for estimation might cause undependable decision-making [10]. Therefore, the determination of healthcare key performance indicators requires a many of knowledgeable professionals [13].

Numerous factors affect healthcare performance, and due to numerous constraints, it is unrealistic for administrators to enhance them simultaneously [14]. Consequently, these indicators must be ranked and prioritized according to their importance, which is represented by calculating their weight, to know what the most critical factors are that affect healthcare management [15].

The performance measures within a critical success factor (CSF) will link daily activities to the organization's strategies and ensure that all operational processes are in line with their mission and objectives [16]. Furthermore, CSF must be specific, measurable, and unique, which will help healthcare organizations prioritize their KPIs based on their efforts and resources and facilitate better decision-making [17]. Subsequently, our contribution can be summarized as follows:

- Analyze the previous literature studies to identify the most frequent CSFs in measuring and evaluating hospital performance.
- Presented different models that were used for identifying the KPIs from 2017 to 2023.
- Presented the most frequently used CSFs in measuring and evaluating healthcare performance.

2. RESEARCH MOTIVATION

Despite numerous studies on monitoring and evaluating healthcare performance, there remains a lack of agreement on the most critical KPIs across diverse healthcare settings. Hence, the motivation for conducting this study is as follows:

- Determine and analyze the most frequently employed KPIs within the healthcare sector from 2017 to 2023.
- The results of the most frequent KPIs from 2017 to 2023 will provide valuable insights to inform future KPI development for the Yemeni healthcare environment, which will be the next step in knowing the priority ranking of KPIs in Yemen. Knowing that there is no previous study that covers this area.
- Identify standard KPIs that other researchers could depend on for the development of Yemeni healthcare

KPIs.

3. RELATED WORK

Over the last few decades, performance management in healthcare organizations has gained significant interest from academics and has become an important study area. Numerous studies were carried out to determine the efficacy of healthcare services. For instance, in [3], the authors used a BSC methodology to develop KPIs and SPSS to determine the significant indicators within four categories (service quality, finance, learning and growth, and internal process) in Ghana's healthcare in sub-Saharan Africa. The associated KPIs were classified using literature research and a questionnaire survey. From the analysis, 17 indicators were identified, including 4 quality indicators, 3 financial indicators, 3 learning and growth indicators, and 7 indicators related to business strategy and operations. The study scope was restricted to three facilities services (cleaning management services, waste, and hospital estate).

In [5], based on the BSC, a literature analysis of 218 indicators was undertaken, and the indicators were grouped into four perspectives (Finance, Internal Process, Learning and Growth, and Customer). The experts' panel and Delphi technique were used to assess the significance of the indicators. The metrics were weighted using a simple additive weighting approach before being selected as the hospital's KPIs. As a result of this study, 22 indicators were carefully chosen for the KPIs of hospitals, 10 indicators were carefully chosen from an internal process perspective, and 5, 4, and 3 indicators were chosen in finance, learning and growth, and customer, respectively. Although this model is adaptable and may be updated to adjust for variances in target hospitals, it has not been evaluated or tested.

In [13], the authors identified healthcare FM KPIs in Turkey that were ranked in terms of quality, time, and cost and divided into six classes (user aspect, environmental aspect, maintenance and repair aspect, emergency and safety management, physical aspect, and lifecycle cost). In this study, ninety-eight FM KPIs were discovered in the literature review. These KPIs were estimated by ten professionals, and the survey outcomes were analyzed with the AHP-integrated PROMETHEE technique to determine their significance. As a result of this study, fifty FM KPIs were identified, and six of them were discovered to be the most significant FM KPIs as CSFs. In comparison to previous studies, the analysis revealed some similarities and differences between China, Hong Kong, and Turkish FM KPIs.

In [14], we merged DHHFLTSs with the DEMATEL method for analyzing relationships between

healthcare performance indicators and used the method (TOPSIS) to order them. The approach was demonstrated by an applied example in a rehabilitation hospital in China. Accordingly, the findings, "Incidents/Errors, Accidents/Adverse Events, Nosocomial Infection, and Length of Stay, are recognized as important indicators for healthcare management. Despite its benefits, the findings of the study were unable to be generalized due to the limited sample size.

In [18], the authors identified critical KPIs influencing health sector performance in Algerian hospitals through a pandemic crisis. In this study, KPIs have been classified into four groups to help decision-makers focus on human and technical factors to improve health system performance during times of crisis. Sixty-two indicators were identified from both a literature review and in-depth interviews with the professionals and then divided into four clusters (Social Sustainability Indicators, Economic Sustainability Indicators, Indicators of Internal Process, and Technical Indicators). The Smart PLS approach was used to evaluate the data. As an outcome of the study, 18 critical KPIs were initiated to assess healthcare performance during the crisis period.

In [19], the authors offered a logical framework that demonstrated the interrelationships between the indicators used to rank the KPIs using the SLR-IFD approach. Eight critical indicators were discovered, and sixteen associations among the indicators were recognized using FCM and FDEMATEL. Patient safety information availability, inventory availability, responsibility, patient satisfaction, innovation, and technology, employee satisfaction, and average hospital stay are critical indicators. Related to the weaknesses of this study, the data collection was not done efficiently due to the hospital's medical team's extreme workload brought on by the Corona epidemic.

In [20], the authors focused on private hospitals and developed a flexible strategy to select and rank performance metrics in the Klang Valley area of Malaysia by using balanced scorecard perspectives in terms of feasible and relevant indicators for monitoring and measuring the performance of private hospitals in Malaysia. 44 performance indicators were identified from the literature review and deep interviews with an expert. They were then filtered using a questionnaire and SPSS. The Microsoft Excel 2010 application was used to compute the weightiness (rank) of each performance measure and prioritize them depending on their importance. As a result of this study, 31 BSC performance measures were identified.

In [21], the authors established a model for identifying critical success factors by integrating linguistic

Z-number and DEMATEL approaches for assessing the appropriate interdependence of performance indicators and determining KPIs for hospital management in Chinese rehabilitation facilities. The findings show that accidents/adverse events, incidents/errors, infection ratio, pass rate, length of stay, and nursing technology are the most significant KPIs for the application. Regarding the significance of this study, the study offered a case study to verify the validity of the suggested mode in a rehabilitation hospital in China.

In [22], the authors established a benchmarking model for monitoring and measuring the healthcare facility management performance at Shanghai Municipal Hospital. The Delphi method and AHP are used to extract the ranked indicators of HFM. This model is based on five dimensions, including customer satisfaction, cost-effectiveness, management efficacy, energy and resource efficiency, and operation and maintenance efficiency. The results of this study show that the top two primary measures are cost-effectiveness and customer satisfaction, and "staff cost-effectiveness, cleaning satisfaction, electricity power efficiency, transferring efficacy, and average response time for maintenance" are the CSFs regarding each primary performance indicator. The model tested its feasibility in a public hospital.

In [23], the authors proposed a new model for assessing the performance of a sustainability healthcare supply chain in Indonesia that integrates the BSC with DEMATEL and ANP to conclude the weights of indicators, perspectives, and sustainability aspects and the cause-effect relationship between them. The finding of this research was that, regarding the BSC perspective, innovation and learning influenced all the perspectives, whereas the customer viewpoint is the most significant for hospital performance. In terms of sustainability, the economic aspect is most important, followed by the social and environmental aspects. The CSFs are profit, quality of service, revenue, customer satisfaction, and stakeholder satisfaction. Despite its advantages, the number of experts who evaluated the indicators was small (only seven experts).

In [24], the authors build a model for estimating the performance of sustainability aspects and intangibility assets that relate to human resources for the healthcare supply chain based on the BSC perspective and DEMATEL. The indicators were recognized via the literature and verified by a survey of seven experts. This study represents the relationship between perspectives and indicators on the SHSCPM and uses these relationships to design the BSC strategy map. The finding was that indicators of customer perception were the most significant compared to other indicators;



in terms of sustainability aspects, indicators on the economic aspect were most significant compared to indicators on environmental and social aspects; and finally, human resource and customer indicators were the main factors for SHSCPM. The model wasn't evaluated and validated by a healthcare service provider, which was a study weakness.

In [25], the authors represented an empirical case study to develop a Linguistic Evidential DEMATEL approach to determine KPIs for holistic hospital management by using the ER method and the 2-tuple linguistic method discussed in this model that visualizes the causal relationships between the performance indicators and determines the significant indicators. As a result of this study, accidents and adverse events, nosocomial infection, incidents and errors, and the number of operations and procedures are significant and influential indicators. Also, the indicators of length of stay, bed occupancy, and financial measures are considered significant indicators. Despite its contribution, the finding can't be generalized since a small sample of healthcare experts was used to collect data.

In [26], the authors evaluated the relationship between key indicators of hospital performance by grouping them into four BSC perspectives and prioritizing indicators using the DEMATEL technique. Selecting the most significant indicators depended on the literature review, an expert panel, and the Delphi technique. 22 KPIs had been selected as the most proper indicators for hospital performance measurement. This model was adaptable and tested in the public hospitals of Shiraz, Iran.

4. METHODS AND MATERIALS

In this paper, we conduct a systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines suggested by [24]. The PRISMA 2020 statement provides redesigned reporting guidance to cover systematic reviews that reflect advances in methods to identify, select, appraise, and synthesize studies [27]. Three main steps were used for this study, which are detailed below: Identification, screening& eligibility, and inclusion.

4.1. IDENTIFICATION

The first step was to identify the articles that concentrate on KPIs and the healthcare sector via searching on IEEE, SpringerLink, MDPI, Wiley Online Library, and the Emerald database. Based on the electronic database search result, there are numerous relevant articles with keywords ("identifying" OR "analyzing" key performance indicators") AND ("healthcare sectors" OR "healthcare

facility management").

4.2. SCREENING & ELIGIBILITY

As a result of the identification phase, 11559 relevant articles were obtained and represented in Table 1. The

Table 1. Search Results from a Journal Database.

Database Journal	Total Article
Springer	5,302
Science Direct	4,355
IEEE	42
MDPI	120
Wiley online library	177
Emerald	1561
Total	11559

screening phase was conducted on titles and abstracts. We rejected 11490 articles based on exclusion criteria (Table 2). 69 articles were obtained through an eligibility process. The well-organized process of eligibility screening in a systematic review or systematic map establishes which evidence will be accessible to address a systematic review or systematic map question [28].

In this phase, we reviewed the full-text articles and determined which evidence fulfilled the following eligibility criteria:

- Identifying the KPIs must cover overall healthcare facility management (FM).
- Identifying the previous studies that used techniques of data analysis for ranking and calculating their KPIs weight in addition to identifying their importance levels.
- Identifying previous empirical research studies that offer conclusions from first-hand information sources.

Table 2. Including and Excluding Criteria.

Include	Exclude
<ul style="list-style-type: none"> - Studies include keyword search. - Studies published between the period of 2017–2023 - Published in the English language - Full-length peer-reviewed studies - Article, Journal studies 	<ul style="list-style-type: none"> - Studied outside the domain of the research. - published before 2017. - Not published in the English language. - No full-length peer-reviewed studies - Books, Chapter, Thesis, Magazine White Paper Abstract

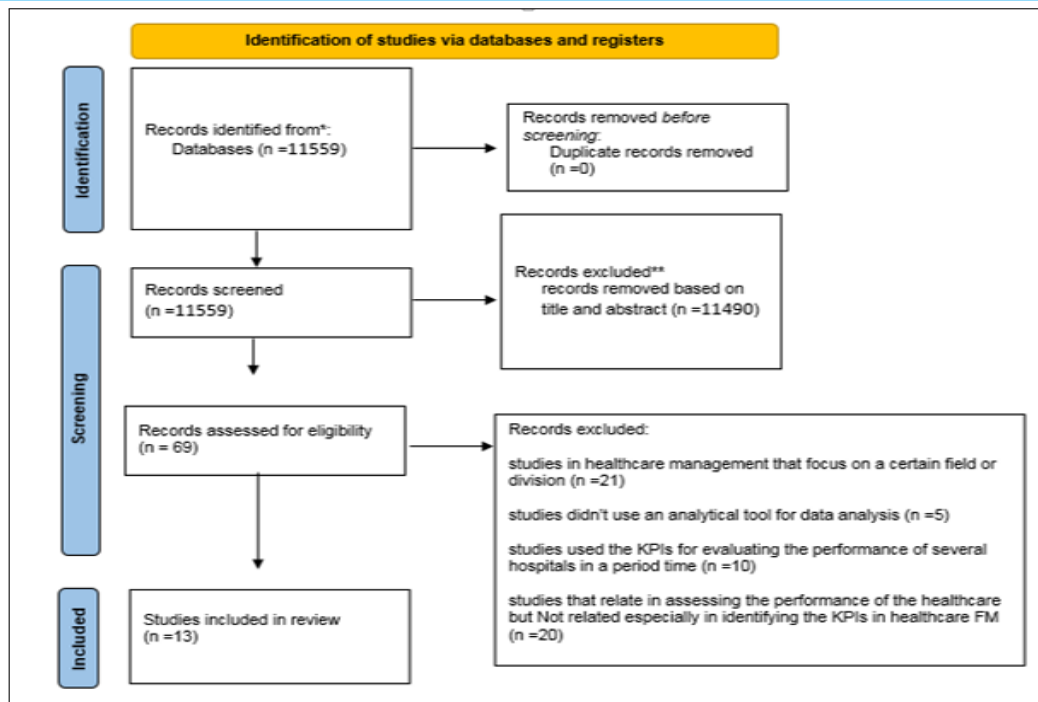


Figure 1. PRISMA 2020 flow diagram for new system review which included a search of the database.

4.3. THE INCLUDED STUDIES

These investigations' primary objective was to ascertain the CSFs for healthcare facility management. Among the 69 articles that were obtained through the eligibility process, 51 articles were excluded for the following reasons:

Studies didn't cover the whole healthcare FM in identifying the KPIs (n = 21).

Studies didn't use techniques of data analysis for ranking and calculating the KPI's weight to identify their importance levels (n = 5).

Studies used the KPIs to compare the performance among several hospitals in a period (n = 10).

Studies related to assessing the performance of healthcare but not, especially in identifying the KPIs in healthcare FM (n =20).

As a result, 13 studies met the eligibility criteria and were included in the qualitative analysis.

5. COMPARATIVE ANALYSIS

Firstly, in this study, the search process identified 11559 publications. Based on the title and abstract screening, 11490 articles were rejected. In the second phase, 69 articles were carefully chosen, and after reviewing the full texts of the selected articles, 56 articles were eliminated due to not meeting eligibility criteria, and only 13 articles matched the eligibility criteria as shown in Fig. 1. The comparative study of the selected studies is summarized in Table 3.

6. RESULT AND DISCUSSION

Numerous studies have discussed how to determine the KPIs utilized to assess hospital performance. The analysis of selected studies showcased a variety of KPI categories, limitations, methodologies, and case studies, enriching the understanding of the current landscape of healthcare performance measurement. Despite limitations such as small sample sizes and a lack of validation in some studies, the scope and depth of the research provide a solid foundation for future work in this area. Among the huge number of KPIs, 40 CSFs were extracted from the results of their studies, and after removing the duplicate indicators and ignoring the indicators that were repeated, 18 indicators were used to measure the hospital performance.

According to [29], the best practice in selecting CSFs should be limited between five and eight, regardless of the organization's size. As a result, indicators that are often considered CSFs that affect service quality and improve medical management efficiency are: (Patient satisfaction, incidents/errors, Cash flow, infection rate, Length of stay, Average waiting time, Number of accidents per year, Bed occupancy) and the indicators excepted are (Employee satisfaction, Rate of Patient complaints preventive maintenance, quality of service, Ratio of total revenue to total costs, Average training hours per employee, Stakeholder satisfaction, Staff turnover, air conditioning quality). The study analysis results are summarized in Table 4.

Table 3. Existing Healthcare Key Performance Indicators Studies.

Ref	KPIs Categories	CSF	Limitation	Methodology	Case Study
[3]	Divided into four clusters by adopting the BSC typology (service quality, finance, learning and growth, and internal process business).	To improve FM performance, seventeen KPIs were defined. Qualitative aspects include timely service delivery and response times, as well as service reliability (correct and dependable service delivery). Professionalism (FM staff's attitude and manners), problem-solving ability, appearance of FM personnel and equipment, and efficiency of the assistance desk. Finances: prompt/timely cash release for FM jobs, percentage of the FM budget that management has authorized, Cost-effectiveness in the delivery of FM. Learning and growth: development of FM employees, Employee turnover, promotions made, competence (having the necessary abilities), procedures for change management. Internal operations: communication with stakeholders, Attainment of goals and objectives as well as mission and vision, commitment of top management, Utilizing ICT, Achieving the FM contractors' service-level agreement (SLA) management of safety and accidents, FM planning's effectiveness.	The example size used is small and focused on three FM services in gathering data.	BSC typology and SPSS.	Ghana's health care in sub-Saharan Africa
[5]	Classified into BSC perspectives (finance, customer, learning and growth, and internal processes).	22 indicators were carefully chosen for the KPIs of hospitals. Finance measurements include revenue ratio to total costs, medicine and material costs, hospital deductions, and personnel expenses as a percentage of total costs. learning and growth factors are employee absenteeism rate, staff turnover, training costs per capita, and staff satisfaction rate. Internal Process: average length of stay, personal satisfaction after discharge, number of beds occupied, rate of hospital infections, number of beds turned over, rate of clinical mistakes, rate of mortality, average length of stay in the emergency room, time spent waiting, and canceled procedures. Customer: the services that are available to visitors and family, customer satisfaction, and complaint rate.	The sample size was small (five experts).	Mixed method of BSC with SAW technique and Delphi method.	Shiraz University of Medical Sciences



Ref	KPIs Categories	CSF	Limitation	Methodology	Case Study
[13]	KPIs are categorized under the following six areas: environmental aspect, user aspect, emergency and safety management, maintenance and repair aspect, physical aspect, and lifecycle cost.	Estimating the profile of resource/energy load (lighting, plug loads, water, heating, and cooling, etc.), estimation of indoor quality and air parameters, the annual number of accidents, the Condition index, the ratio of preventive maintenance, and the ratio of overall O& M expenses to healthcare revenue for each patient bed in a building are the most important factors.	The sample size that was used in this study was small (only ten respondents).	AHP integrated with the PROMETHEE method	Turkey
[14]	There are no specific categories.	Key indicators for healthcare include incidents /errors, accidents/adverse incidents, infection ratio, and length of stay.	In this investigation, a limited sample size is used.	Fused the DHHFL TSs approach with the DEMATEL method.	China
[18]	Categorized into four groups: internal processes, technological, societal, and economic.	The most essential factors are human factors (infection rate, clinical and medication errors) and technical factors (time of the laboratory test, facility location, and sufficient air).	The sample size that is used in this study is small.	The Delphi method in data collection and the Smart-PLS method to analyze the data.	Algeria
[19]	Twenty-nine indicators were identified and analyzed via a literature review to find the interrelationship among these indicators.	inventory availability, patient safety information availability and responsibility patient satisfaction, innovation and technology, employee satisfaction, and length of stay in the hospital are critical indicators.	Due to the hospital's medical team's extreme workload brought on by the Corona epidemic, the data-gathering process wasn't effective.	hybrid FCM-FDEMATEL approach	Iran
[20]	Organized into four BSC viewpoints (learning and growth, internal business processes, customers, and finance).	The most important indicators are: Returned on investment (ROI), inventory turnover rate, cash flow, debt ratio, net profit margin (NPM), average profit per hospital bed, cost per patient day, ROE (return on equity), and current ratio are financial indicators. The customer perspective includes the number of patient complaints and satisfaction. Perspectives on IBP: medical error rate; and Perspectives on Learning and Growth: average number of hours spent on training per employee.	No testing or validation of the model was done.	The questionnaire survey was used to select the useful indicators. SPSS and MS Excel 2010 applications for data analysis.	Malaysia

Ref	KPIs Categories	CSF	Limitation	Methodology	Case Study
[21]	Fall into 5 dimensions (social benefit, quality, operating efficiency, financial status, and development ability).	The most important success factors are nosocomial infection, length of stay, nursing technology pass rate, incidents/errors, and accidents/adverse.	In the present study, a limited sample size has been used.	A language Z-number and the DEMATEL method combined	China
[22]	Divided into five dimensions, including customer satisfaction, cost-effectiveness management efficacy, energy and resource efficiency, and operation and maintenance efficiency	In terms of primary indicators, customer satisfaction and cost-effectiveness are in the top two, respectively. The significant success factors for each are employee cost-effectiveness, satisfaction with cleaning, electrical power efficiency, effectiveness of transfer, and typical repair response time.	This study is limited to a public hospital only.	The Delphi method and AHP were used to determine the HFM priority performance indicators.	Shanghai
[23]	Classified into the sustainability aspects (economic, environmental, and social) based on the BSC perspective.	Profit, revenue, customer and stakeholder satisfaction, and quality of service are the important success factors for the hospital's evaluation.	The sample size that was used in this study was small (seven experts).	Combining BSC with ANP and DEMATEL methodologies.	Indonesia
[24]	The indicators were categorized using the BSC perspective (financial, customer, learning and growth). And internal processes)	The key factors of SHSCPM were customer indicators, which included delivery, stakeholder satisfaction, patient loyalty, quality of service, customer satisfaction, and human resources.	There is no implementation of this model among health-care service providers.	Integration of BSC with DEMATEL	Indonesia.
[25]	Indicators fall into three perspectives (patient, employee, and management).	Accident and adverse events, infection ratio, incidents and errors, operations and procedures, length of stay, bed occupancy, and financial indicators are critical success factors for hospital performance.	The sample size was small (five experts).	Combining the 2-tuple interval linguistic model with the evidential reasoning method	China
[26]	The indicators are grouped into four BSC perspectives.	Customer perspectives include the satisfaction of patients and the number of patient complaints. Learning and growth perspective: staff growth and satisfaction internal process perspective: bed occupancy and clinical errors.	The results extracted from the research were not compared with the results of previous studies.	BSC topology with the DEMATEL method	Iran

Table 4. Summary Result of CSFs Frequently Used in Previous Studies.

NO.	Critical successful factors	Number of repetitions	Reference
1	Patient Satisfaction	7	10,8,13,14,15, 12,18
2	Incidents/errors(Clinical and medication)	7	3,6,10,11,17,15,18
3	Cash flow	5	10,4,12, 15,17
4	Infection rate	5	6,3,11,15,17
5	Length of stay	5	8,6,11,15,17
6	Number of accidents per year	4	1,6,11,17
7	Bed occupancy	4	15,10,17,18
8	Average waiting time	3	4,12,15
9	Employee satisfaction	3	8,15,18
10	Rate of Patient complaints	3	15,10,18
11	Quality of service	3	13,4,14
12	Average training hours per employee	3	10,15,18
13	Preventive maintenance	2	1,12
14	The ratio of total revenue to total costs	2	15,17
15	Stakeholder satisfaction	2	13,14
16	Staff turnover	2	15,4
17	Air conditioning quality	2	3,1

7. CONCLUSION AND FUTURE WORK

The healthcare performance measurement system plays a crucial role in assessing the effectiveness of hospital management. This study has provided valuable insights into the critical success factors (CSFs) for measuring and evaluating healthcare performance. The review of related work underscored the significance of identifying and prioritizing KPIs in healthcare management across different settings and highlighted the diverse methodologies and approaches used in various studies. Utilizing a systematic review that adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews) guidelines, the most frequent critical performance indicators (CSFs) were identified, including patient satisfaction, cash flow, infection rate, length of stay, average waiting time, number of accidents per year, incidents and errors, and bed occupancy. The findings not only contribute to the understanding of hospital management performance but also provide a foundation for the future development of key performance indicators (KPIs) in the Yemeni healthcare environment. Further work is needed to build a business-intelligent healthcare model for monitoring and measuring the performance of the Yemeni healthcare environment that includes:

- Identifying healthcare FM KPIs that are used for monitoring the performance of the Yemeni healthcare environment.
- Prioritize FM KPIs for the Yemeni healthcare environment based on a multi-criterion decision-making

(MCDM) approach.

- Design a BI dashboard for monitoring and evaluating Yemeni healthcare management performance.

REFERENCES

- [1] G. Demirdögen, Z. Işık, and Y. Arayıcı, "Determination of business intelligence and analytics-based healthcare facility management key performance indicators," *Appl. Sci.*, vol. 12, no. 2, p. 651, (2022).
- [2] A. Fotovatfard and G. Heravi, "Identifying key performance indicators for healthcare facilities maintenance," *J. Build. Eng.*, vol. 42, p. 102838, (2021).
- [3] A. Burlea-Schiopoiu and K. Ferhati, "The managerial implications of the key performance indicators in healthcare sector: A cluster analysis," *Healthcare*, vol. 9, p. 19, (2020).
- [4] D. Amos, C. P. Au-Yong, and Z. N. Musa, "Developing key performance indicators for hospital facilities management services: A developing country perspective," *Eng. Constr. Archit. Manag.*, vol. 27, no. 9, pp. 2715–2735, (2020).
- [5] M. Khalifa and P. Khalid, "Developing strategic health care key performance indicators: A case study on a tertiary care hospital," in *Procedia Computer Science*, pp. 459-466, (2015).
- [6] L. Zhang, R. Liu, S. Jiang, G. Luo, and H. C. Liu, "Identification of key performance indicators for hospital management using an extended hesitant linguistic dematel approach," *Healthcare*, vol. 8, no. 1, p. 7, (2019).
- [7] J. H. Lai *et al.*, "Importance of hospital facilities management performance indicators: Building practitioners' perspectives," *J. Build. Eng.*, vol. 45, p. 103428, (2022).
- [8] A. H. Dolatabad, H. A. Mahdiraji, A. Z. Babgohari, J. A. Garza-Reyes, and A. Ai, "Analyzing the key performance indicators of circular supply chains by hybrid fuzzy cognitive mapping and fuzzy dematel: Evidence from healthcare sector," *Environ. Dev. Sustain.*, pp. 1–27, (2022).
- [9] J. Lai and P. L. Yuen, "Identification, classification and short-listing of performance indicators for hospital facilities management," *Facilities*, vol. 39, no. 1/2, pp. 4–18, (2021).
- [10] F. Behrouzi and A. Ma'aram, "Identification and ranking of specific balanced scorecard performance measures for hospitals: A case study of private hospitals in the Klang valley area, Malaysia," *The Int. J. Health Planning Management*, vol. 34, no. 4, pp. 1364–1376, (2019).
- [11] S. Jiang, H. Shi, W. Lin, and H. C. Liu, "A large group linguistic z-dematel approach for identifying key performance indicators in hospital performance management," *Appl. Soft Comput.*, vol. 86, p. 105900, (2020).
- [12] Y. Li, L. Cao, Y. Han, and J. Wei, "Development of a conceptual benchmarking framework for healthcare facilities management: Case study of Shanghai municipal hospitals," *J. Constr. Eng. Manag.*, vol. 146, no. 1, p. 05019016, (2020).
- [13] E. B. Leksono, S. Suparno, and I. Vanany, "Integration of a balanced scorecard, dematel, and ANP for measuring the performance of a sustainable healthcare supply chain," *Sustainability*, vol. 11, no. 13, p. 3626, (2019).
- [14] E. B. Leksono, S. Suparno, and I. Vanany, "Development of performance indicators relationships on sustainable healthcare supply chain performance measurement using balanced scorecard and dematel," *Int. J. on Adv. Sci. Eng. Inf. Technol.*, vol. 8, no. 1, pp. 115–122, (2018).
- [15] H. Rahimi, Z. Kavosi, P. Shojaei, and E. Kharazmi, "Key performance indicators in hospital based on balanced scorecard model," *Health Manag. Inf. Sci.*, vol. 4, no. 1, pp. 17–24, (2017).



- [16] H. Gao, H. Chen, J. Feng, X. Qin, X. Wang, S. Liang, et al., "Balanced scorecard-based performance evaluation of chinese county hospitals in underdeveloped areas," *J. Int. Med. Res.*, vol. 46, no. 5, pp. 1947–1962, (2018).
- [17] S. L. Si, X. Y. You, H. C. Liu, and J. Huang, "Identifying key performance indicators for holistic hospital management with a modified dematel approach," *Int. journal environmental research public health*, vol. 14, no. 8, p. 934, (2017).
- [18] H. Rahimi, J. Bahmaei, P. Shojaei, Z. Kavosi, and M. Khavasi, "Developing a strategy map to improve public hospitals performance with balanced scorecard and dematel approach," *J. DEMO Neoscriber V3 single*, no. 19, p. 7, (2018).
- [19] S. Aujirapongpan, K. Meesook, P. Theinsathid, and C. Maneechot, "Performance evaluation of community hospitals in thailand: An analysis based on the balanced scorecard concept," *Iran. J. Public Health*, vol. 49, no. 5, p. 906, (2020).
- [20] K. Pourmohammadi, N. Hatam, P. Shojaei, and P. Bastani, "A comprehensive map of the evidence on the performance evaluation indicators of public hospitals: A scoping study and best fit framework synthesis," *Cost Eff. Resour. Allocation*, pp. 1–22, (2018).
- [21] H. C. Liu, "A theoretical framework for holistic hospital management in the japanese healthcare context," *Health Policy*, vol. 113, no. 1-2, pp. 160–169, (2013).
- [22] S. L. Si, X. Y. You, H. C. Liu, and J. Huang, "Identifying key performance indicators for holistic hospital management with a modified dematel approach," *Int. journal environmental research public health*, vol. 14, no. 8, p. 934, (2017).
- [23] C. El Morr and H. Ali-Hassan, *Healthcare, data analytics, and business intelligence*. Analytics in healthcare: a practical introduction, pp. 1-13, (2019).
- [24] M. J. Page et al., "Updating guidance for reporting systematic reviews: Development of the prisma 2020 statement," *J. Clin. Epidemiol.*, vol. 134, pp. 103–112, (2021).
- [25] X. Gu and K. Itoh, "Performance indicators: Healthcare professionals' views," *Int. J. Health Care Qual. Assur.*, (2016).
- [26] E. W. Kairu, "Effects of balanced scorecard on performance of firms in the service sector," M.S. thesis, University of Nairobi, (2013).
- [27] I. M. Okwo and I. M. Marire, "Performance measurement in business organizations: An empirical analysis of the financial performance of some breweries in nigeria," *Res. J. Finance Account.*, vol. 3, no. 11, pp. 48–57, (2012).
- [28] M. J. Sousa, A. M. Pesqueira, C. Lemos, M. Sousa, and Á. Rocha, "Decision-making based on big data analytics for people management in healthcare organizations," *J. Med. Syst.*, vol. 43, pp. 1–10, (2019).
- [29] M. Sony, J. Antony, and G. L. Tortorella, "Critical success factors for successful implementation of healthcare 4.0: A literature review and future research agenda," *Int. J. Environ. Res. Public Health*, vol. 20, no. 5, p. 4669, (2023).